

# GEOMETRICAL EFFECTS ON THE ELECTROMAGNETIC RADIATION FROM LIGHTNING RETURN STROKES

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The morphological difference between the electromagnetic radiation-field waveforms of "first" and "subsequent" return strokes in cloud-to-ground lightning flashes is well known [4] and can be used to identify the formation of new channels to ground [5]. This difference is generally believed due to the existence of branches on first-stroke channels, whereas subsequent strokes re-illuminate only the main channel of a previous stroke; but experimental evidence for this hypothesis is relatively weak. [2] have argued for the influence of channel geometry on the fine structure of radiation from subsequent return strokes by comparing the field-change waveforms recorded at the same station from strokes within the same flash and between different flashes of both natural and triggered lightning. The present paper introduces new evidence for both of these hypotheses from a comparison of waveforms between sensors in different directions from the same stroke.

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Sferic Array [3] has recorded electric-field-change waveforms simultaneously at several stations surrounding the ground-strike points of numerous, natural, first and subsequent return strokes. Such data are available from the five-station sub-networks in both Florida and New Mexico. With these data it has been possible for the first time to compare the waveforms radiated in different directions by a given stroke. Such comparisons are of interest to assess both the effects of channel geometry on the fine structure of subsequent-stroke radiation and the role of branches in the more jagged appearance of first-stroke waveforms.

This paper presents multiple-station, time-domain waveforms with a 200 Hz to 500 kHz pass-band from the Florida sub-network for both first and subsequent return strokes at ranges generally between 100 and 200 km. An example of a first stroke recorded by three stations in Florida is given in Figure 1. Figure 2 shows an example of a subsequent

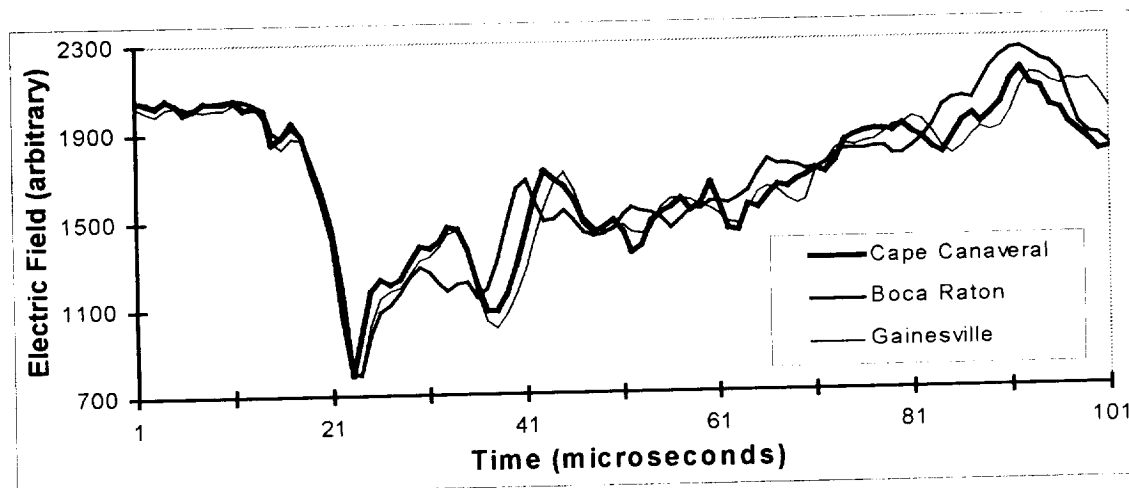


Figure 1 -- First return stroke recorded at three stations in the Florida network (see Fig.3)

stroke from four stations of the same network. The station layout in Florida is given in Figure 3, with the locations of these two strokes indicated.

The differences among waveforms of the same stroke, received at stations in different directions from the lightning channel, are often obvious, though not always as large as might be expected. A simple, piece-wise linear, transmission-line model [1,6] is used to simulate features of these waveforms. With this model it is possible to give plausible ex-

planations, in terms of channel geometry and stroke-propagation velocity, both for the major differences among the waveforms observed in different directions from some strokes and for the surprising similarity among the waveforms from others. It is concluded that the frequent, direction-dependent differences constitute strong evidence for the effects of channel geometry, whereas the occasional lack of such differences is not evidence against those effects.

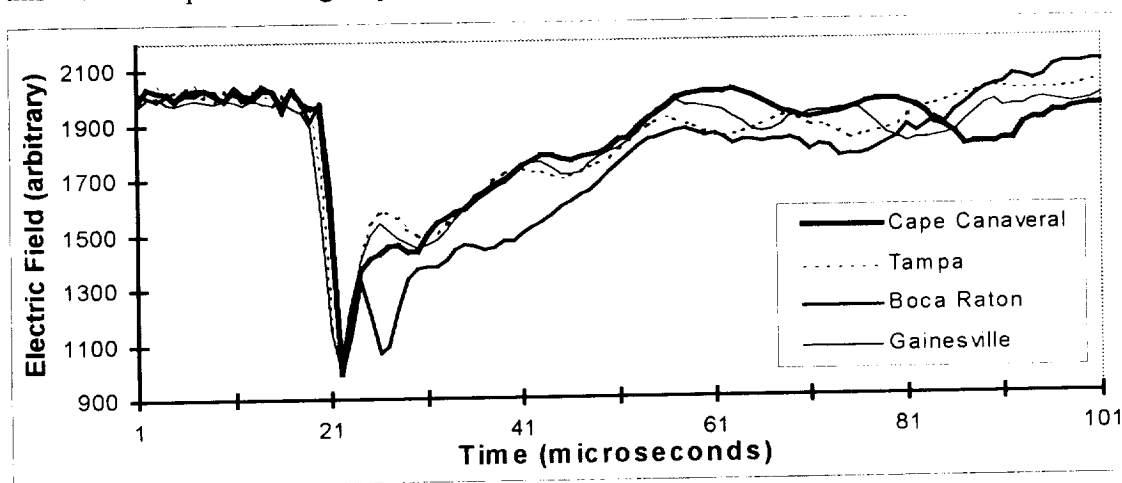


Figure 2 -- Subsequent return stroke recorded at four of these stations

#### References

- [1] Le Vine, D.M., and J.C. Willett. Comment on the transmission-line model for computing radiation from lightning. *J. Geophys. Res.*, 97, 2601-2610, 1992.
- [2] Le Vine, D.M., and J.C. Willett. The influence of channel geometry on the fine scale structure of radiation from lightning return strokes. *J. Geophys. Res.*, 100, 18,629-18,638, 1995.
- [3] Smith, D.A., K.B. Eack, J. Harlin, M.J. Heavner, A.R. Jacobson, R.S. Massey, X.M. Shao, and K.C. Wiens. The Los Alamos Sferic Array: Ground truth for the FORTE satellite. Los Alamos National Laboratory Internal Publication. LAUR-00-4883, 2000.
- [4] Weidman, C. D., and E. P. Krider. The fine structure of lightning return stroke wave forms. *J. Geophys. Res.*, 83 (C12), 6239-6247, 1978. Correction, *J. Geophys. Res.*, 87 (C9), 7351, 1982.
- [5] Willett, J.C., D.M. Le Vine, and V.P. Idone. Lightning-channel morphology revealed by return-stroke, radiation-field waveforms. *J. Geophys. Res.*, 100, 2727-2738, 1995.
- [6] Willett, J.C., and D.M. Le Vine. On the current distribution in lightning subsequent return

strokes, in *Proceedings, 10th International Conference on Atmospheric Electricity*, Osaka, Japan, 10-14 June 1966, pp. 492-495, 1996.

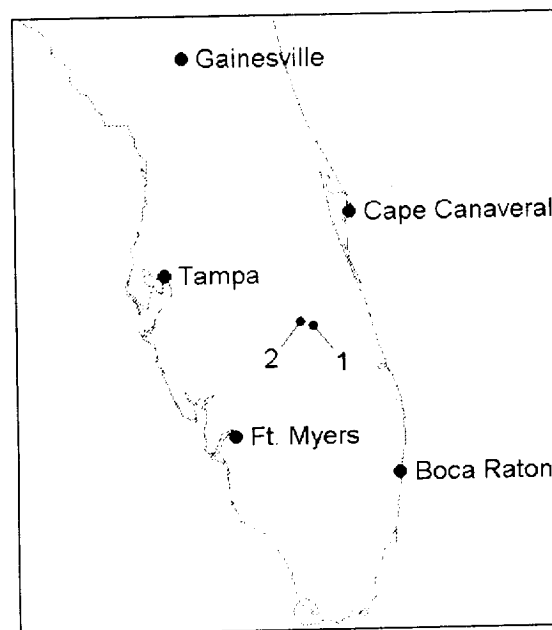


Figure 3 -- Map of Florida network showing locations of first (1) and subsequent (2) strokes